

Comment on “High-Precision Determination of the Electric and Magnetic Form Factors of the Proton”

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In a recent Letter, Bernauer, *et al.* [1] present fits to the proton electromagnetic form factors, $G_E(Q^2)$ and $G_M(Q^2)$, along with extracted proton charge and magnetization radii based on large set of new, high statistical precision ($<0.2\%$) cross section measurements. The Coulomb corrections (CC) they apply [2] differ dramatically from more modern and complete calculations, implying significant error in their final results.

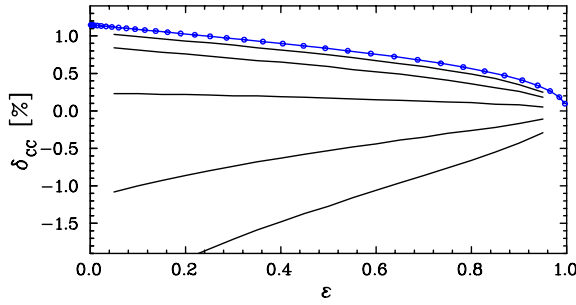


FIG. 1: (Color online) The Coulomb correction from Ref. [2] (circles), evaluated at the mean Q^2 of the experiment, and the full CC result [3] for $Q^2=0.01$ (top), 0.03, 0.1, 0.3, and 1.0 GeV^2 (bottom). TPE calculations [4, 5] yield similar results, with a somewhat weaker Q^2 dependence at low Q^2 .

It has been shown that two-photon exchange (TPE) corrections are important in the extraction of the form factors [6] and the charge radius [7] of the proton. At low Q^2 , the Coulomb correction (representing the soft part of the TPE) yields the dominant contribution and has a significant Q^2 dependence at very low Q^2 [3–5]. In the analysis of Ref. [1], the applied correction [2, 8] is the $Q^2 \rightarrow 0$ limit of the full calculation:

$$\delta_{CC} = Z\alpha\pi[\sin(\theta/2) - \sin^2(\theta/2)]/\cos^2(\theta/2). \quad (1)$$

Figure 1 shows the CC applied in Ref. [1] along with the full Q^2 -dependent result [3]. The full correction is outside of the 50% uncertainty assumed in Ref. [1] for all data above $Q^2 = 0.06 \text{ GeV}^2$. By 0.1 GeV^2 , the small- ε correction has changed by 1% which will modify G_M and its Q^2 dependence, altering the extracted magnetic radius. The full δ_{CC} is 2–3% lower for $Q^2 > 0.3 \text{ GeV}^2$ and low ε : a change several times the total uncertainties on the individual cross sections (which do not include any systematic uncertainties, although all kinematic settings have inflated statistical errors to account for non-statistical deviations from the global fit [8]). The fits include estimates of systematics and theoretical (TPE) uncertainties

which are essentially negligible at small scattering angles and at most $\sim 0.5\%$ at large angles [8], still much smaller than the error in δ_{CC} .

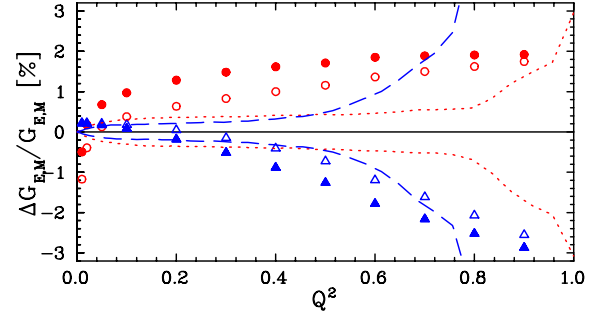


FIG. 2: (Color online) Estimated change in G_M (red circles) and G_E (blue triangles). The points show the impact of replacing the CC of Ref. [1] with the full CC [3] (solid symbols) or TPE calculation [5] (hollow symbols), using dipole form factors and assuming that the cross section data cover $0.3 < \varepsilon < 0.9$. The dotted (dashed) lines show the fit uncertainties on G_M (G_E) [1].

Figure 2 shows the estimated impact of the full CC or TPE calculations on a direct Rosenbluth separation of the form factors. This suggests that proper implementation of the corrections will shift the G_M results by more than 2–3 standard deviations, bringing the ratio $\mu_p G_E/G_M$ into better agreement with recent high-precision polarization measurements [9].

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- [1] J. C. Bernauer et al., Phys. Rev. Lett. **105**, 242001 (2010).
 - [2] W. A. McKinley and H. Feshbach, Phys. Rev. **74**, 1759 (1948).
 - [3] J. Arrington and I. Sick, Phys. Rev. C **70**, 028203 (2004).
 - [4] D. Borisyuk and A. Kobushkin, Phys. Rev. **C75**, 038202 (2007).
 - [5] P. G. Blunden, W. Melnitchouk, and J. A. Tjon, Phys. Rev. C **72**, 034612 (2005).
 - [6] J. Arrington, W. Melnitchouk, and J. A. Tjon, Phys. Rev. **C76**, 035205 (2007).
 - [7] P. G. Blunden and I. Sick, Phys. Rev. C **72**, 057601 (2005).
 - [8] J. C. Bernauer, Ph.D. thesis, Johannes-Gutenberg Universität Mainz (2010).
 - [9] X. Zhan et al. (2011), arXiv:1102.0318.